8.5.5 Without any significant coordination, disparate systems will achieve analog interoperability using a common base-line interoperability technology.[26]

8.5.5.1 This can serve both analog speech or data that is converted to a speech bandwidth signal in a fashion similar to using modems over telephone. Data transmitted via analog transmission are subject to no more coordination than generally practiced today requiring compatible modems on both sides of a telephone link. Data speed is significantly less than compared to direct digital transmission.

[26] We note that the PSWAC Interoperability Subcommittee has recommended such a common transmission mode (analog FM) for such interoperability. We note that current generation digital cellular telephones also support FM transmission mode.

APPENDIX A

SUMMARY OF TECHNICAL PRESENTATIONS

1. *American Mobile Satellite Corporation (AMSC)* by Mr. Ed Gilbert, Telecommunications Consultant, American Mobile Satellite Corporation.

Mr. Gilbert indicated that on April 7, 1995, AMSC's first satellite was launched into geo-synchronous orbit over the equator south of Brownsville, Texas. This instituted satellite communications from small, mobile, affordable terminals the size of a PC notebook computer, with coverage over most of the continental United States, Hawaii, much of Alaska and the Caribbean to 200 miles offshore. Voice, data and fax are possible through automatic connections to the public networks. AMSC is of the view that, in addition to regular telecommunications, this service provides exceptional backup during emergencies if terrestrial systems are destroyed or overloaded. AMSC is especially interested in public service organizations willing to assist with the testing program for these systems and introduction of initial service.

2. *E.F. Johnson* by Mr. Steve Nichols, Director of Marketing, E.F. Johnson.

Mr. Nichols indicated that E.F. Johnson provides trunked networks and sales and service worldwide, offering a complete turnkey system. They offer trunked systems covering the 450, 800, and 900 MHz bands and conventional products in the 150, 450, 800, and 900 MHz bands. They currently support systems for government and public safety, including the Washington State Department of Transportation (with 3100 radios and over 100 channels in rugged topography), the Island of Puerto Rico (with 1500 radios and 68 channels that include public safety uses), Amoco (at 900 MHz with over 2200 radios using 80 repeaters in 5 states, including refinery and off-shore platform use), and the Interstate Power Company (with 450 radios on 47 channels in 4 states). E.F. Johnson stated that their distributed logic trunking approach creates affordable trunking systems for small departments, municipalities and users who thought they couldn't afford trunking. Also, E.F. Johnson indicates that its flexible system topology and unique simulcast capabilities create an efficient trunking solution for large-scale regional applications. E.F. Johnson advocates their systems as offering a simple, low-cost migration path forward to digital spectrum efficiency. Their "open architecture" protocol is adaptable to all bands, and is easily migratable to a variety of efficient digital modulation schemes. They are continuing to develop improved technology in simulcasting, network architectures, and new spectrum efficient modulation techniques.

3. *AirTouch Cellular* by Mr. Michael Alcalay, Manager Public Relations, AirTouch Cellular.

AirTouch Cellular is developing alliances to gain strong working partnerships with law enforcement and emergency response teams. They are working to educate law enforcement agencies on how cellular service differs from landline communications. AirTouch advocates the use of cellular communications during emergency events. Cellular has proven instrumental during emergencies with voice, data, and paging technologies. AirTouch is working to educate Californians on how to use 911 appropriately through a statewide education campaign with the Cellular Carriers Association of California, the California Highway Patrol and other cellular carriers. AirTouch suggest that alternative star or pound numbers be developed for quicker access to law enforcement. They seek to promote understanding of how cellular technology works, including its limitations. They believe cellular technology is being used to help law enforcement and emergency services communicate effectively during times of emergencies.

4. *American Paging, Inc. (API)* by Mr. John Schaaf, President and Chief Executive Officer, American Paging, Inc.

API's systems can apply defense technologies for public safety. Through American Messaging Services, a joint venture between API and Nexus Telecommunications Systems, they are developing and marketing patented Nexus spread-spectrum technologies for two-way paging, location, and telemetry services. The Nexus spread spectrum frequency hopping technology provides a low cost return overlay network. It has a 1:1 receiver to transmitter ratio, which lowers capital requirements and lowers operating costs. It provides two-way paging, life paging (for those in need of an organ transplant), vehicle location services, personal location services, and security and monitoring services.

5. *Nextel Communications, Inc.* by Ms. Natalee Roan, Director, Marketing, Nextel Communications, Inc.

Nextel Communications currently offers a digital product which integrates 2-way dispatch, mobile phone, alphanumeric messaging, and voice mail all within a single hand-set on Nextel's own network. The Nextel system currently covers the east and west coasts, Las Vegas, Reno, as well as the Chicago-Detroit-Milwaukee-Toledo and Denver-Oklahoma-Missouri-Kansas clusters. They employ Motorola's iDen technology, which allows greater privacy than current analog radio or analog cellular networks can offer because it is fully digital. Through the use of Nextel's products and services, agencies which currently have different private communications networks can now communicate to one another over our national network. Examples of successful deployment of inter-agency communications using Nextel's communications system are Oklahoma City bombing, the Northridge earthquake in Los Angeles, as well as the 1995 papal visit to New York and Baltimore.

6. *QUALCOMM, Inc.* by Mr. Kevin Kelley, Vice President, External Affairs, QUALCOMM, Inc.

QUALCOMM is an integrated wireless communications company that manufactures products and provides service and operations. QUALCOMM advocates and is currently developing secure ubiquitous portable interoperable communications using code division multiple access (CDMA) techniques over the commercial cellular infrastructure. They believe CDMA provides for best frequency reuse and provides control of mobile transmit power by operating at less than one one-hundredth of the power of a typical FM mobile unit. CDMA techniques allow multipath signal combining. CDMA allows soft handoffs between cell sites. CDMA techniques also provide for variable-rate vocoders, sectorization and forward error correction.

7. *Ericsson, Inc.* by Mr. Ernest Hofmeister, Manager, Advanced Systems, Ericsson.

Ericsson believes that it can support any technology direction to achieve increased spectrum efficiency. Digital technology advances have and will continue to enable spectral efficiency improvements through advancements in digital speech coding, spectrum efficient modulations, and traffic capacity. The accumulated spectral efficiency increase over that for one user in a 25 kHz channel from these three advances is estimated to range from a factor of four conservatively to a factor of 16 optimistically. The additional capacity needed for user growth and the implementation of advanced data services is expected to exceed the capacity growth achieved through spectral efficiency improvement. As a result, Ericsson believes additional spectrum for public safety will be needed. Ericsson believes that TDMA technology is a proper system choice and is developing a next generation Prism digital private land mobile radio system based on TDMA. This system has a factor of four spectrum efficiency increase. A half-rate speech coder which seems feasible within the next five years would further increase the spectrum efficiency by another factor of two. This system also includes a high-data bandwidth-on-demand capability that will aggregate two TDMA slots for a 16 kilobytes-per-second rate in a 12.5 kHz channel to address future data needs for image or video data. Ericsson believes the TDMA system choice allows leverage of the large cellular research and development investment for the benefit of the private land mobile radio community, including public safety.

8. *Motorola, Inc.* by Mr. Allen Davidson, Electronics Engineer, Motorola, Inc.

Motorola proposes an engineering methodology for projecting spectrum demands. They believe that it is important to separate the technological implementation of solutions from the technological requirements for solutions. The predominant technology in the year 2010 may have just emerged, or may still be waiting to emerge. Because no one knows for sure what the details of the future hold, it is more practical and useful to project the probable attributes of tomorrow's radio environment than it is to guess how product inventories may look in 15 years. This is possible because trends for electronic component integration, cost, size and a variety of other attributes have obeyed the patterns of steep experience curves for at least the last 30 years. Motorola recommends that a mathematical model be developed to project quantities of public safety spectrum required after each of the subcommittees do their respective jobs. This mathematical model could be developed similarly to the one submitted by the Coalition of Private Users of Emerging Multimedia Technologies in their Petition for Rule Making with respect to spectrum allocations for advanced private land mobile communications services, filed with the Federal Communications on December 23, 1993. Except for an optimum channelization structure, which can only be determined as it interrelates with blocking, loading, and other considerations that directly impact the net spectrum requirement, each subcommittee would produce elements of such a mathematical model, describing the relationships between need and required spectrum in terms of objective dimensions, quantities and volumes.

9. *NTT America* by Mr. Steve Crowley, Consulting Engineer, NTT America.

Nippon Telegraph and Telephone Corporation (NTT) has developed a new modulation technology, Real Zero Single Sideband (RZ SSB). The inherent spectrum efficiencies of SSB still make it quite attractive; the SSB modulation process does not take up any excess RF bandwidth with emissions outside the information bandwidth. Two breakthrough receiver technologies provide great immunity against severe fading encountered in land mobile environments. The first is a new demodulation method using the zero crossings of received SSB signals, eliminating performance-limiting circuits found in the conventional SSB receiver. The second breakthrough is a new equal-gain antenna combining method. The information bandwidth of RZ SSB is identical to that of conventional telephone lines, and the technology supports signals on telephone circuits without additional equipment. The entire information spectrum of 300 Hz to 3.4 kHz is carried without degradation. RZ SSB supports multiple media including analog voice with natural sound characteristics and graceful degradation, allowing easy speaker identification. RZ SSB supports digital encrypted voice using recent advanced speech coders such as PSI-CELP. Data transmission is at speeds up to 19.2 kbps in a 5 kHz channel (3.84 bits/sec/Hz). Also possible is image as well as text transmission by facsimile (with unprecedented quality in fading channels), still pictures (JPEG), and slow-scan video. RZ SSB also supports Time Division Duplex technology allowing full-duplex operation in a single 5 kHz channel. Laboratory experiments and field tests of RZ SSB prototype equipment verify predicted performance. The cost of RZ SSB technology is comparable to that of existing equipment.

10. *SEA, Inc.* by Mr. David Thompson, President and Chief Executive Officer, SEA, Inc.

SEA is a manufacturer of narrow-band single-sideband technology, presently used at 220 MHz. SEA does not tout narrow-band technology as a panacea for the solution of all public safety needs; however, SEA finds that 5 kHz narrowband technology works very well. SEA has chosen to utilize linear modulation techniques to achieve spectrum efficiency. Narrowband linear modulation's strengths include coverage, low capital cost, good voice recognition, and excellent audio. Its weaknesses are that it is relatively unknown and pioneered by less well known companies in the mobile communications industry.

11. *Securicor Radiocoms, Ltd.* by Mr. Mike Bayly, North American Business Development Manager, Securicor Radiocoms, Ltd.

Traditionally, the way to meet shortages of spectrum has been to divide radio channels, generally giving the user poorer quality. Technology can help this spectrum shortage (or spectrum wastage) with improved efficiencies. Specifically, linear modulation can achieve very-narrow-band channelization, down to 6.25 or 5 kHz. This has been accomplished at 220 MHz. Linear modulation is an enabling technology that permits transmission of very-narrow-band digital, analog, voice, data or video information by using (1) transparent tone in band (TTIB), (2) fast feedforward signal regeneration (FFSR), and (3) Cartesian Loop linearisation. Securicor's linear modulation technology is being used in the 220 MHz frequency band in the United States. Linear modulation products are also now being manufactured in the United Kingdom pursuant to the new UK 5 kHz MPT 1376 standard. Linear modulation provides clear voice signals that can be encrypted. It reduces the adverse effects of Doppler, multi-path, Rayleigh and phase distortion. It provides high speed data capability at greater than 14.4 kilobytes per second. It offers more channels per megahertz. It results in less power consumed and less power transmitted. It offers a graceful transition from today's standards to a new technology.

12. *AT&T* by Dr. Gary Schlanger, Advanced Communications Laboratory, AT&T Labs.

The wireless telecommunications industry in the United States today is extremely complex with many existing and emerging applications and spectrum allocations. All users are looking for: a single phone, a single address, universal roaming, integrated services (such as paging, voice, image), and performance comparable to wireline. Terminals that support multiple spectrum bands, multiple modes (protocols), and multi-media (voice, data, FAX) can accomplish these objectives. There have been dramatic improvements over the past decade in public commercial cellular service with respect to technology advances (size, battery life, quality, reliability, etc.) and decreased service costs. New features like Priority Access and Channel Assignment are of particular interest to the public safety community. In AT&T's view, the public safety community should leverage Public Network capabilities wherever and whenever possible to satisfy their expanding requirements.

13. *Technology for Fire Services* by Chief Gary Cates, Berkeley Fire Department, Berkeley, California

Chief Cates made a presentation from the standpoint, he said, of one who is not a technological expert. Still, he must use the technology and sometimes encounters its limitations, especially with regard to interoperability. Chief Cates discussed communications problems experienced during the 1989 Loma Prieta Earthquake and the 1991 Oakland/Berkeley Firestorm, two major situations in the San Francisco Bay Area. Over 400 fire units from throughout the State of California were involved in the 1991 incident. The patchwork of mutual-aid communications meant to facilitate inter-agency communication did not work well due mostly to technical problems. For example, the fourteen fire departments in Alameda County operate on two 800 MHz (Ericsson and Motorola), two UHF, and a number of VHF systems. The Ericsson and Motorola systems are supposed to be interoperable, but technical and operational problems persist. Chief Cates stressed that there is a national need for radio technology that provides the following: (1) initial dispatch capabilities, (2) in route communications, (3) allow for command and tactical subdivisions, (4) compatibility, (5) versatility, (6) interoperability, (7) hardened for severe conditions. Chief Cates made an appeal on behalf of public safety agencies for federal funding assistance to develop and purchase new radio technologies. He said that money spent now in improving public safety communication systems would be paid back many times over in terms in life and property saved in future disasters.

14. *Police Full-Motion Video Surveillance* Lieutenant Hank Borders, Berkeley Police Department, Berkeley, California

Lieutenant Borders showed a video presentation describing how his police department uses video surveillance as an aid to its narcotics law enforcement program. The video system described uses relatively simple technology, and sends wide-bandwidth National Television Systems Committee (NTSC) video of an RF frequency of 2.475 GHz. The video camera is focused on a park where the transactions are made. The camera is located behind an apartment window and is remotely-controllable from the police department at the Berkeley Hall of Justice. The camera can be panned and tilted remotely by tone control over a standard VHF or UHF radio voice channel. The video from the camera is fed to a microwave transmitter. In terms in practical considerations, it was noted that the system worked fine transmitting through small trees, but with thicker vegetation, or when trees are wet, signal quality can suffer from the increased attenuation. The police department is able, to some extent, to reflect a usable signal off buildings if a direct path does not obtain between the transmit and receive sites. Lieutenant Borders reports some problems using the 2.475 GHz frequency. It is the only frequency available to Public Safety for this type of use. The frequency, however, is shared with broadcasters in the San Francisco area, who use it for electronic news gathering. Many undercover operations involve extended transmissions which causes conflict with some broadcasters who want the frequency for their news gathering purposes.

15. *Technology Needs for Emergency Management* by Mr. Donald E. Root, Jr., California Governors Office of Emergency Services

Mr. Root described a telephone interconnect system that was successfully deployed during the 1991 Oakland, California fire. Architecturally, the system can be described as a wireless link in the local loop and operates on the 5.850 GHz amateur radio band. The system is described as having several advantages over alternatives. With regard to cellular telephone, cellular frequencies are quickly saturated during a disaster (usually by civilians) and are thus often unavailable to public safety users. Furthermore, cellular telephone antenna towers can themselves become victim to disaster. Another emergency communications technique to which the van-microwave system is favorably compared is one provided by the local telephone company. In major incidents, Pacific Bell will often attempt to deploy additional wire lines at an incident scene. One problem with this is the long time it takes for the phone company to establish such lines. Another problem is that, in the event the incident command center has to be moved (as is often the case in a fire situation), the land lines have to be moved as well, which can take too much time. By contrast, the system described by Mr. Root simply requires driving the van to the new command center.

16. *Advances in Wireless Technology* by Professor Kamilo Feher, University of California at Davis

Dr. Feher's presentation discussed his company, Digicom, Inc., and his various patented technologies that have applications in wireless communications, generally in the modulation area. Some of these technologies are described in his new book, "Wireless Digital

Communications: Modulation and Spread Spectrum Applications." Much of Dr. Fehers remarks related to his invention Feher's Quadrature Phase Shift Keying (FQPSK), a spectrally-efficient implementation of QPSK that is said to have an approximately 5 dB performance improvement over GMSK. Dr. Feher says his technologies allow better power and spectral efficiencies than can be achieved with conventional modulation and RF techniques. Ultimately, he says, his technologies can lead to increased battery life and smaller-sized products along with more robust performance.

17. *Overview of Video Technology* by Mr. Thomas Christ, Chairman, HDS, Inc.

Mr. Christ stated that law enforcement entities constitute the largest number of public safety video users. RF video links, such as X-band FM video transmissions, have been used in the federal community for investigative purposes for the last 25 years. Use of video communications for public safety purposes, however, is relatively new. Only since the late 1980's has there been extensive tactical use of video transmissions. Requirements of small size and power efficiency exist for investigative reasons. Public safety agencies are now able to avail themselves of video communications because new technologies permit transmission of video via a voice-grade channel. The critical enabling technologies that permit achievement of this objective are (1) video compression techniques, (2) fast cheap microprocessors, and (3) wireless common carrier communications grids. Small FM video transmitters operating in the 33 MHz slot between 2,450 to 2,483 MHz band constitute the preponderance of current public safety video use. This spectrum was made available for this use in the late 1980's. Most public safety video use is now under Part 90 Subpart B in that spectrum, except for applications for long-term fixed use.

18. *Mobile Satellite Systems* by Ms. Susan Moore, SkyTel, for Mr. Edward Gilbert, AMSC

Susan Moore highlighted dramatic advances in technology that have been made in three areas critical to effective management of emergencies: (1) the ability to communicate anywhere, any time; (2) to know location precisely; and (3) to overlay data base information to assist in response planning and execution. In the U.S., three "Big LEOs" have been licensed by the FCC. Big LEO means satellites in low or medium earth orbit operating above 1 GHz and providing both voice and data. "Little LEOs" operate below 1 GHz and provide data service only. The Big LEOs plan to offer service late in this century or early in the next with dual mode satellite/cellular telephones. Currently, ORBCOMM is the only Little LEO in operation. It has two satellites in orbit, and beta testing is in progress. To provide continuous coverage over the U.S., 26 satellites are necessary. This constellation is planned for full deployment by the end of 1997. As these systems are placed in operation and their user terminals tested in quantity, much more will be learned about their ability to support emergency communications. Satellites permit interoperability via the Public Networks. Interconnections to a common network can satisfy many interoperability requirements, especially for interactions at the command post level. There, if systems can access the public switched telephone network (PSTN), information can be shared and made available to a wide audience of users without creating a new infrastructure. Satellite systems have a particular advantage here when terrestrial systems are stressed. Their access to the PSTN is via a distant gateway station unlikely to be affected by a localized or even widespread emergency.

Additionally, common interfaces lend themselves to interoperability. For example, the link between mobile satellites and SkyTel allows data to pass between two networks based on data protocols and formatting without being restricted by any particular standard.

19. Advanced Digital Wireless Technologies by Dr. Gregory Stone, Consultant, INS/CECOM

Dr. Stone discussed certain wireless digital communications fundamentals. He explained that bandwidth and information transfer capacity are not synonymous. Bandwidth is the range of frequencies within which performance, with respect to other some characteristic, falls within specific limits. Information transfer capacity, on the other hand, is the rate of information transfer at maximum channel capacity. He commented on the symbol transmission rate theoretical limit in terms of the Nyquist minimum bandwidth. He discussed the channel capacity theoretical limit in terms of the Shannon-Hartley channel capacity theorem. He explained that the ideal channel: (1) is linear time invariant; (2) has only Additive White Gaussian Noise (AWGN) as a perturbation; and (3) is distortion free. A benign channel is perturbed by some linear distortion and AWGN in the detection system. A mobile radio channel, however, (1) is a randomly time variant linear channel; and (2) is perturbed by (a) lognormal variations in signal amplitude, (b) Rayleigh variation in signal amplitude and phase, (c) Doppler shift in frequency, (d) time dispersion or time variance of the channel's impulse response, and (e) AWGN. The solution is to deperturb a time variant non-linear mobile channel to create a quasi-linear phase time invariant channel. In bandpass (passband) systems (i.e., wireless) digital information is transformed by the modulation process. The parametric performance of any wireless information transport system is dependent upon how each of these transformations is implemented.

Dr. Stone also discussed the following areas of projected technological evolution: (1) source coding and compression; (2) channel coding, EDAC, modulation, and frequency translation; (3) radio frequency power amplification; (4) advanced linearisation and detection techniques; (5) synchronization; (6) digital signal process and signal-to-noise ratio improvements; (7) information transfer capacity and information transfer rate; (8) antenna technology; (9) system architectural features and frequency reuse; and (10) spectrum use efficiency. Dr. Stone then reviewed other advanced digital wireless technological considerations, including: (1) system modeling, simulation and performance validation; (2) common transmission protocols; (3) multimode/multiband subscriber equipment; (4) covert communications support; and (5) public carrier conveyances.

APPENDIX B
TECHNOLOGY INVENTORY SUMMARY

COMPANY	TECHNOLOGY DESCRIPTION - Note 1	SIGNAL TYPES Note 2	BANDWIDTH	CHAN. Note 3	ACCESS	DATA RATES Note 4	VOCODER	ENCRYPTION	C/D/F Note 5
Transcrypt	FDMA Project 25	V, LD	12.5 kHz	1	FDMA	9,600	IMBE	Yes	D
Ericsson	EDACS	V	25/12.5 kHz	1	FDMA	N/A	N/A	No	C
Ericsson	EDACS/Aegis Standard	V, LD, SV	25/12.5 kHz	1	FDMA	9,600	AME	Yes	C/D
Ericsson	EDACS/PrismNarrowband	V, LD, SV	12.5 kHz	1	FDMA	9,600	IMBE	Yes	D
Ericsson	EDACS/Prism-TDMA	V, LD, PIC, VID	12.5 kHz	2	TDMA	16,000	IMBE	Yes	D
Motorola	IDEN/MIRS	V, LD, HD	25 kHz	3 or 6	TDMA	64,000	VSELP	No	C
Motorola	ASTRO-FDMA Project 25	V, LD	12.5 kHz	1	FDMA	9,600	VSELP/IMBE	Yes	C/D
NTT America	RZ SSB	V, LD, SV, PIC	5/6.25 kHz	1	FDMA	19,200	PSI-CELP/VSELP	Yes	D
NTT America	RZ SSB	V, LD, SV, PIC	5/6.25 kHz	2	TDD	19,200	PSI-CELP/VSELP	YES	D
NTT America	RZ SSB	V, LD, SV, PIC	10/12.5 kHz	2 or 4	TDMA	38,400	PSI-CELP/VSELP	YES	D
EF Johnson	LTR	V	25 kHz	1	FDMA	9,600	N/A	No	C
EF Johnson	Multi-Net	V	25 kHz	1	FDMA	9,600	N/A	No	C
EF Johnson	LTR-2	V	25 kHz	1	FDMA	9,600	N/A	No	F
EF Johnson	Multi-Net 25	V, LD	25/12.5 kHz	1	FDMA	9,600	IMBE	Yes	F
Midland	FDMA Project 25	V, LD	25/12.5 kHz	1	FDMA	9,600	IMBE	Yes	D

NOTES:
#1 Trademark descriptions are used for some descriptors.
#2 V = Voice, LD = Low Speed data (defined as up to 19.2 kbps), HD = High Speed data (defined as > 56 kbps, SV = Slow video, PIC = Snapshot Picture, VID = Video
#3 Channels per carrier
#4 The raw data rate is used.
#5 C = Currently type accepted, D = Developmental, F = Future technology

APPENDIX C

TECHNICAL PARAMETERS FOR FORECASTING SPECTRUM DEMAND

The model which has been selected for the computation of the spectrum need of public safety is described in the report of the Spectrum Subcommittee. That model calls for technological parameters to be projected through the year 2010 for the identified user service needs, and then used to compute the spectrum needed. The user service needs which have been identified by the Operational Requirements Subcommittee are: Voice Dispatch, Telephone Interconnect, Transaction Processing, Facsimile, Snapshot, Remote File Access, and Slow and Full Scan Video. The following provides a detailed description of the technology parameters used in the process and identifies a recommended value for each parameter.

TECHNOLOGY PARAMETERS

Description	Abbreviation
RF Transmission Rate	RATE
Error Control and Overhead	ERR
Source Content	SRC
Channel Occupancy	LOAD
Coding Improvement	COD

1.0 RF Transmission Rate (RATE)

The word RATE will be used to designate the RF transmission rate in the model. It is described in bits per second per Hertz (b/s/Hz). The leading edge technology in use was projected to be 3.5 b/s/Hz in the year 2000 and 5.0 in the year 2010. Assuming a 15 year life, the systems in use in the year 2010 will be the accumulation of systems sold starting with those purchased today and including those that will be sold in the year 2010. Those sold today include some which are at the level of about 2.5 b/s/Hz and some that are less than 1.0 b/s/Hz. Those sold in the year 2010 will likewise have a range of values. Projected values are summarized in Table 1.

Table 1
Transmission Rate

Service	b/s/hz
all except video and remote file transfer	1.5
video and remote file transfer	3.5

2.0 Error Control and Overhead (ERR)

In the model, we will use ERR to represent the subject parameter, and it will be expressed in the average percent of transmitted bit rate that is dedicated to this function.

Coding of the information bits allows more and more compression to take place. However, each bit then becomes more important, and the error correcting function then becomes more important. In addition, over time, linear modulation schemes are being used with higher transmission rates. Because of the multipath propagation environment, it becomes necessary to provide synchronization and equalization functions that also may use some capacity.

Table 2
Error Control and Overhead

Today	Future
55 %	50 %

3.0 Source Content (SRC)

The content of the source message to be transmitted is represented by the shortened form SRC in the equations to follow. In the future, it is projected that all services provided will be implemented in a digital format. Therefore, this parameter will be expressed in kilobits per second (kb/s).

The offered load that has been developed in User Traffic Profile White Paper[1] is based on a source content of 6 kb/s per second for all categories except special data, and that will be used herein. For special data, consisting of video and remote file access, it will be prohibitive to limit the channel to such a slow data rate. In Appendix C of the Prediction Model White Paper[2] values are developed for these latter services, and a nominal rate developed there is 384 kb/s. That is the value which will be used for the spectrum computation.

The magnitude of the source content is that which is contained in the state of the art message today, including any coding improvement that has been done to date. Advances in coding

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1 United States Department of Justice, Immigration and Naturalization Service, Headquarters Radio Systems Section, "Public Safety Wireless Communications User Traffic Profiles and Grade-Of-Service Recommendations", March 13, 1996, prepared by Dr. Gregory M. Stone. Referenced here as "User Traffic Profiles White Paper."

2 White Paper "Model For Prediction Of Spectrum Need Through The Year 2010", Version 2.0, May 27, 1996, presented To PSWAC by Motorola Inc. Referenced here as "Prediction Model White Paper."

in the future are addressed in the parameter COD developed below. The resulting content of the advanced features for SRC is summarized in Table 3.

4.0 Channel Occupancy (LOAD)

Channel loading is the portion of time the channel has RF transmitted over it expressed in percent of the total time the channel is available. It is represented by the term LOAD, and is a complex subject that is a function of many parameters. These parameters include the kind and urgency of the message, the number of users of the channel, how many servers are available for the channel, and the length of message and number of them per hour offered by the users.

An example of a situation where a lightly loaded channel is necessary is when a group of scattered police officers are waiting to simultaneously close in on a suspect with a hostage. They operate on a single channel, and It is imperative that when the word go is uttered they all move with the greatest of speed. The channel in use must be very lightly loaded, LOAD less than 5 percent, to assure that the short message will not be blocked.

An example of a situation where a heavily loaded channel can be used involves trunked systems that carry routine messages. Data requests for license plate checks can wait two or three seconds as the officer writes a ticket. A dispatcher request for present location usually takes a few seconds for a voice reply as the officer reaches for the radio to reply. That too will not suffer greatly if two or three seconds of blockage occur. LOAD can be 20 to 25 percent on a single channel system and as much as 70 to 80 percent on 20 channel trunked systems and meet this criteria.

Finally, there are messages that can wait for a few minutes before delivery to the intended party. These may include a FAX sent to an individual driving a car (we recommend that they keep their eyes on the road as opposed to reading a FAX), and E-Mail message, or a long file which is to be used at some time in the future. Single channel systems can be loaded up to 50 percent and 20 channel systems up to 95 percent and provide this service. For purposes of the analysis of spectrum need a value of 55 percent is recommended.

5.0 Coding Improvement (COD)

The coding improvement is a dimensionless factor that describes the anticipated improvement in coding that will take place between the years 1996 and the year 2010. The shortened term COD is used in the model. For various services, the value of COD varies from 1 to 3 as shown in Table 3.

6.0 Recommended Parameters For Model

Based on the discussions above, the technological parameters have been quantified for each of parameters identified are summarized in Table 3.

Table 3
SUMMARY OF TECHNOLOGY PARAMETERS

SERVICE	RATE b/sec/Hz	ERR %	SRC kb/s	LOAD %	COD
Voice Dispatch	1.5	50	6	55	2
Telephone Interconnect	1.5	50	6	55	2
Transaction Processing	1.5	50	6	55	2
Facsimile	1.5	50	6	55	1
Snapshot	1.5	50	6	55	1
Remote File Transfer	3.5	50	384	55	3
Slow Scan Video	3.5	50	384	55	3
Full Motion Video	3.5	50	384	55	3

6.3 APPENDIX C - Interoperability Subcommittee Report

<u>PSWAC/ISC 96-05-037/10</u>
Revised 7/28/96

PUBLIC SAFETY WIRELESS ADVISORY COMMITTEE

INTEROPERABILITY SUBCOMMITTEE

FINAL REPORT

July 29, 1996

INTEROPERABILITY

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Interoperability Subcommittee
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1.0 EXECUTIVE SUMMARY

1.1 Subcommittee Overview

The Interoperability Subcommittee (ISC) is one of five subcommittees formed under the Public Safety Wireless Advisory Committee (PSWAC). The ISC was developed to identify the interoperability requirements of the public safety community and make recommendations to resolve the historical inability of different agencies to communicate with each other, via radio, during routine, emergency and disaster response operations.

Although the "PSWAC mailing list" was quite extensive, the ISC consisted of approximately 150 members, representing the user community, as well as representatives from industry and commercial service providers.

1.1.1 Charter

The Interoperability Subcommittee (ISC) is to identify the interoperability requirements of the public safety community and make recommendations to resolve the historical inability of different agencies to communicate with each other, via radio, during routine, emergency and disaster response operations.

The Steering Committee also tasked the ISC to define Public Safety and Interoperability for all the subcommittees to use in their respective assessments of the current and future for public safety communications. In addition, the ISC defined the term Mission Critical as it is used to describe the importance and priority of communications, particularly as it applied to interoperability and the utilization of various alternative methods.

1.1.2 Report Scope

This subcommittee report outlines and discusses the current communications interoperability requirements and capabilities, as well as the envisioned needs of the future. The subcommittee has considered the interoperability needs that are currently unsatisfied or that have been unsatisfactorily provided. All phases of interoperability have been explored, including command and control functions. These examinations have generally been neutral on technology. The interoperability issues, identified by the Operational Requirements Subcommittee, have also been considered and are addressed in this report.

1.2 Definitions

The Steering Committee tasked the Interoperability Subcommittee to provide a recommended definition of *Public Safety* to be utilized by all the subcommittees in their respective assessments of the current and future requirements for public safety communications. Likewise, the subcommittee decided it was necessary to define what is meant by *interoperability*, before the communications capability could be identified and recommendations developed. The need to develop a definition for *mission critical* was identified during subsequent meetings as various levels of communications interoperability were addressed.

1.2.1 Public Safety

Public Safety was generally defined as a function of government, following both what has historically been the accepted practice, as well as addressing the nature of governmental operations and radio system requirements in the future. Many disciplines are included within this definition, but the common thread throughout is that they are functions of government.

Some non-governmental organizations have some functions which are public safety in nature. One such example is the railroads which may have their own law enforcement and fire protection elements. A sub-heading of *Public Safety Services Provider* includes such public safety elements, but only so far as they are authorized by government. Such services can be included within public safety as long as actual radio authorizations are held by the government organizations.

1.2.2 Public Services

A second definition, *Public Services*, was developed because of public safety's need to interoperate with non-public safety organizations. This definition includes organizations which are suppliers of the nations' basic infrastructures which are required to promote the public's safety and welfare. Some examples include railroads and power utilities.

1.2.3 Interoperability

Interoperability is a communications link which permits units from different agencies to communicate with each other. This link can involve infrastructure elements, or it can allow direct communications between field units without infrastructure support.

1.2.4 Mission-Critical

A *mission critical* communication is one which must be immediate, ubiquitous, reliable, and in most cases secure. *Mission critical* communications require the highest level of assurance that the message will immediately be transmitted and received regardless of the location of the operating units within the designed coverage area. In such cases, system set-up or processing delays are unacceptable and coverage must extend to the operating location of the field units. Most public safety systems that are built for mission critical applications, are designed with extreme care to assure reliable operation in the face of a series of potential system element failures.

1.3 Spectrum

Federal, state, and local law enforcement and public safety agencies rely on radio spectrum for command, control, and execution of operations. Due to the increase in joint operations, interoperability among law enforcement/public safety agencies is a major concern. The existing spectrum allocation is insufficient to meet these existing and future needs and does not support interoperability.

Widespread implementation of interoperability capabilities are hindered by the diversity of radio frequency spectrum in which public safety agencies operate. Ten disparate and separate segments of the frequency spectrum are used for tactical mobile communications by federal, state, and local agencies, spanning 839 MHz of spectrum. No single radio is capable of operating in the numerous radio bands currently used by the federal, state and local public safety organizations, at an affordable price.

The ability to adequately interoperate on voice channels in the future will worsen, if contiguous or near contiguous bands are not allocated for public safety use. The ability to adequately interoperate in the future may become more complex as disparate and/or proprietary technologies are introduced.

1.4 Interoperability Requirements

The ISC defined Interoperability as an essential communication link within public safety and public service wireless communications systems which permits units from two or more different agencies to interact with one another and to exchange information according to a prescribed method in order to achieve predictable results. This communications link is required not only in voice, but in all modes of communication, including low speed data, high speed data and video.

Three basic and different operational requirement levels of interoperability have been identified by the ISC:

1.4.1 Day-to-day

This most frequent type of interoperability is commonly used in areas of concurrent jurisdiction where agencies need to monitor each other's routine communications. This minimizes the need for dispatcher to dispatcher interaction in exchanging information among field units. Interoperability is difficult to implement unless all equipment operates in the same frequency band and within the same type of infrastructure.

1.4.2 Mutual aid

This involves multiple agencies using radios in "on the scene" incidents that are often outside the range of fixed infrastructure. There is often little opportunity for prior planning of different agencies to coordinate the necessary talk groups and frequency assignments.